1st Annual National
Biomimicry Summit and Education Forum (BSEF)
for Aerospace

Aerospace, Biomimicry and other Cool things…

or Neanderthals, Nautilus Shells and NASA - Connecting Past, Present and Future to Expand our Domain of Inquiry and Range of Applications

August 2, 2016

Dr. Vikram Shyam
NASA Glenn Research Center
Cleveland, OH 44135

- Why are we here?
- How did we get here?
  A brief history - the many faces of biomimicry
- Why now? Convergence
- What's new? Neanderthals and Nautilus Shells
- How do we bring it all together?

Challenges – Acceptable Reasons*

- Resources
- Limits of knowledge

Opportunities – Real Reasons*

- Future scenarios
- New frontiers

Capabilities – We have the technology

- People
- Philosophy
- Technology

*reference to speech by NASA administrator Mike Griffin

Synthetic Biology,
artificial evolution…

Hybrid
Manufacturing

Big Data
Analytics

3D Scanning

Art and Design

Physiomimetics

Anthropomimetics

Biomimetics

Paleomimetics

Physioteleology

Healthy, Relevant,
Sustainable Future

Future opportunities and challenges

- Space tourism
- Flying cars, congested airspace
- Solar flares
- Asteroid impact
- US faces competition from Asia and Europe
- Journey to Mars/Moon – radiation, earth-independence

SOFTEE - Self-Organizing Fluidcraft for Terrestrial and Extraterrestrial Exploration

Detect Surroundings

Morph to Optimal state

Detect health and current state of system

Identify pathways to change from current state to optimal state

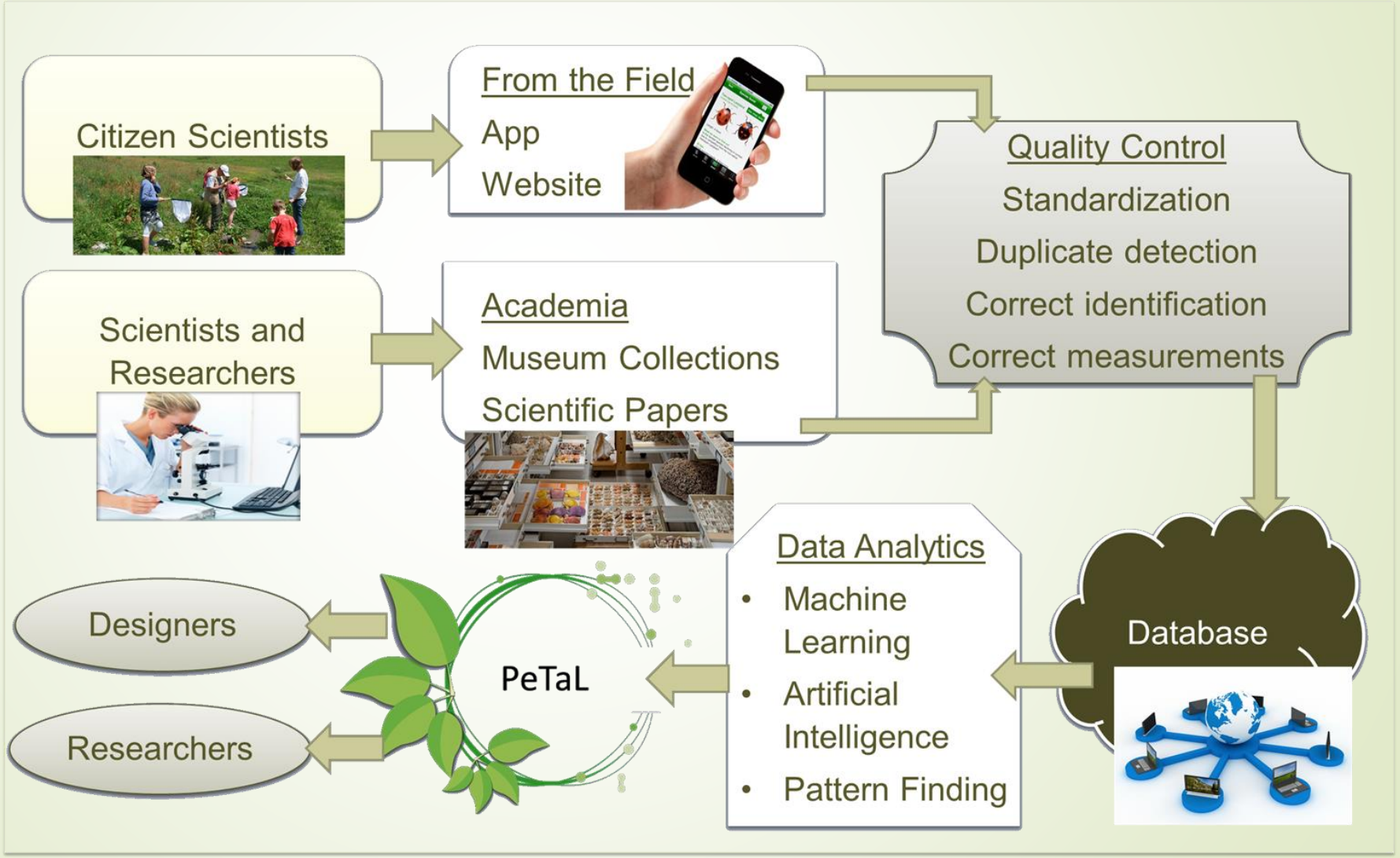
Determine optimal future state

Tools to solve challenges using bio-inspiration

- BioTRIZ - http://www.biotriz.com/
- AskNature – www.asknature.org
- PeTaL – NASA GRC developing this tool – https://www.grc.nasa.gov/vine

Day 1: An Evolving Discipline
Day 2: Architecture, Art…
Day 3: Educational Aspects

PeTaL – Periodic Table of Life



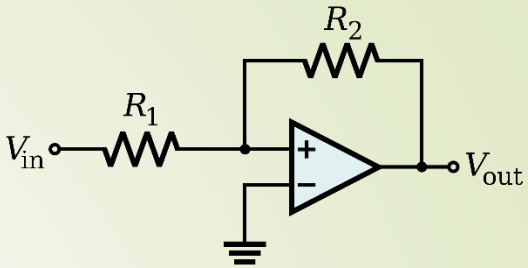
- Why are we here?
- A brief history - the many faces of biomimicry
- Lessons learned from ancestors
- Convergence
- Bringing it all together

Biomimicry as defined by?

- Biophysics (Otto Schmitt, 1957)
- Bioengineering
- Biomechanics
- Biomedical engineering
- Bionics (like life) – Jack Steele (1960)
- Biomimesis, biomimicry (imitation of life)
  - Otto Schmitt (1960)
  - Janine Benyus (1999)
- Others???

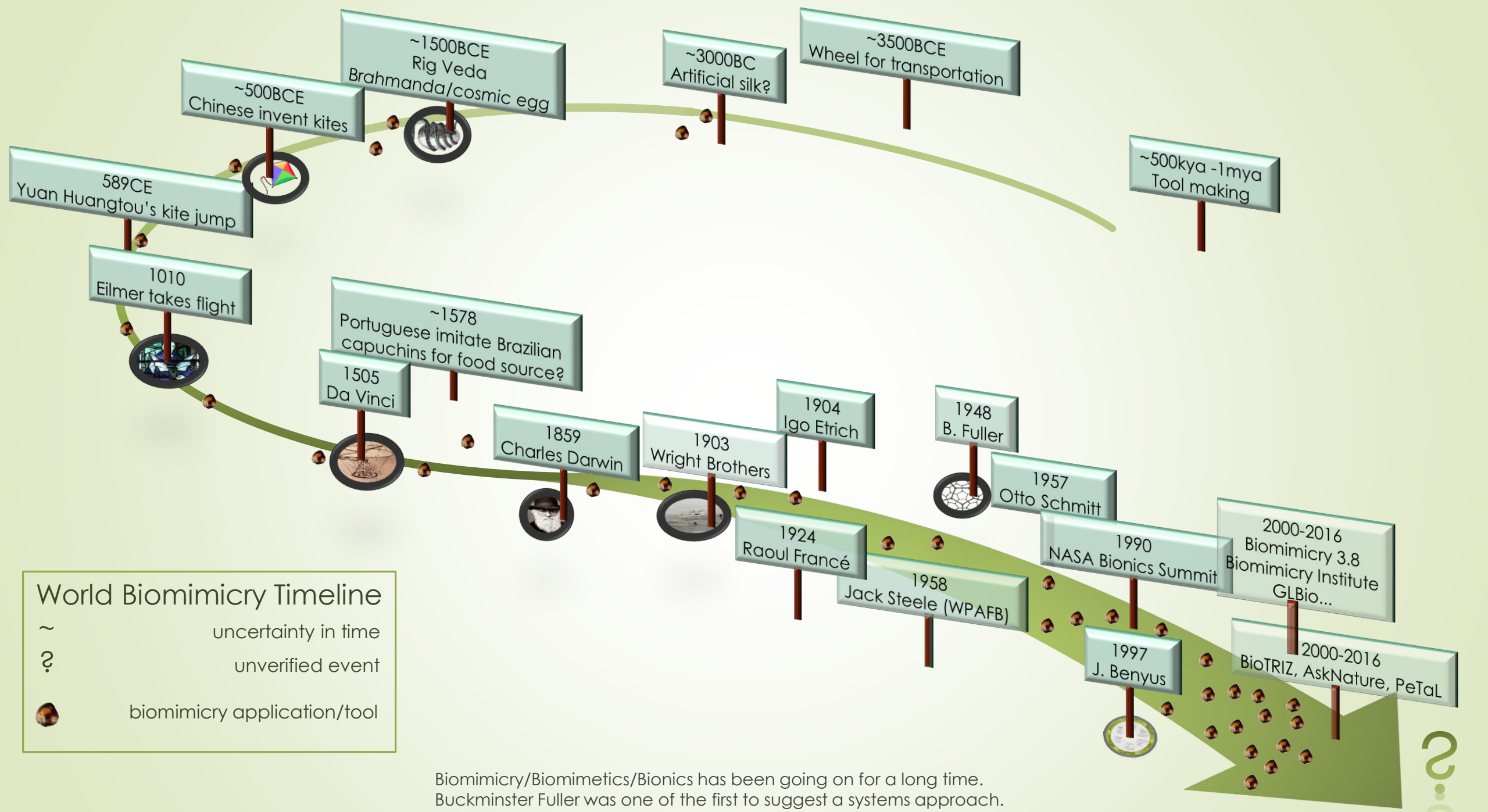
"Terminology is the generalist's biggest enemy but is essential to accomplishing the generalist's goals"

Otto Schmitt



- Ph.D. with majors in Physics and Zoology, minor in mathematics
- Came up with ‘biomimetics’
- Invented Schmitt trigger, cathode follower, differential amplifier…

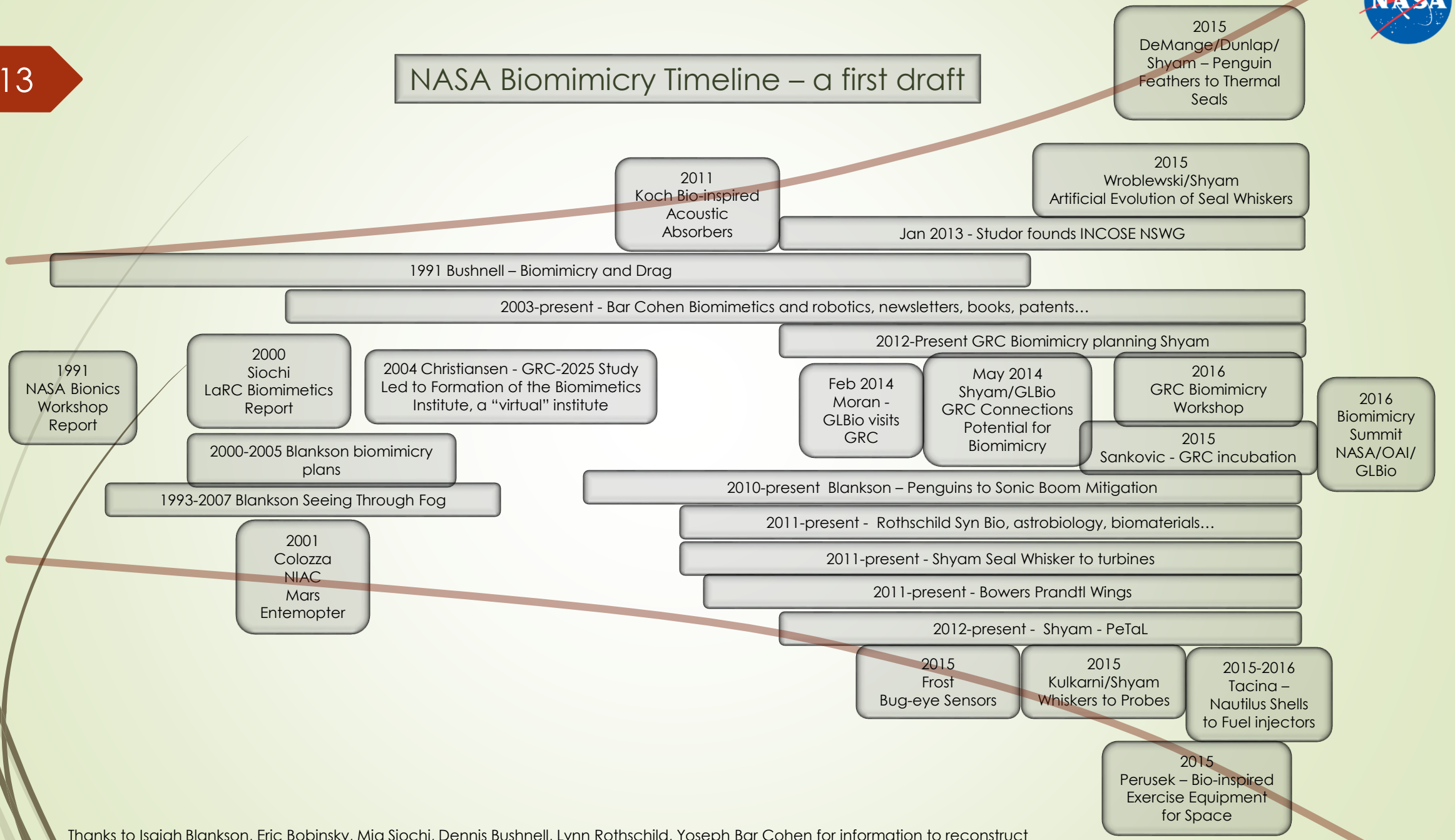
Emphasis on non-invasive observation and analysis



Biomimicry/Biomimetics/Bionics has been going on for a long time.
Buckminster Fuller was one of the first to suggest a systems approach.
Advent of internet, new forms of media helped popularize practice thanks to people like Janine Benyus.

Vikram Shyam, NASA Glenn Research Center, 2016

NASA Biomimicry Timeline – a first draft



Thanks to Isaiah Blankson, Eric Bobinsky, Mia Siochi, Dennis Bushnell, Lynn Rothschild, Yoseph Bar Cohen for information to reconstruct

NASA Contractor Report 177594

Engineering Derivatives from Biological Systems for Advanced Aerospace Applications

Daniel L. Winfield, Dean H. Hering, and David Cole

CONTRACT NAS2-13119
December 1991

NASA
National Aeronautics and Space Administration

1.0 EXECUTIVE SUMMARY

Researchers, designers and engineers have for many years looked toward nature for design ideas and engineering principles that can be incorporated into man-made engineering systems. This concept of mimicking natural systems has been termed bionics or biomimetics. The goal of this study is to document the engineering contributions from the field of bionics and to identify opportunities for accelerated research which may provide innovative solutions, based on design principles derived from nature, to aerospace problems.

One may ask why we should expect that studying biological creatures, who are by necessity restricted to terrestrial environments, will offer any valuable insight for advanced space technology, which is inherently extraterrestrial. There are three responses to such a query.

1) Through natural selection, evolutionary pressures result in biological systems (be they structural, sensory, neural or motor) that conserve material and energy. The resulting small, lightweight, energy efficient (and frequently multifunctional) systems should be of obvious interest for aerospace designs where these are critical design parameters.

2) The performance of biological systems in robust and adaptable, and this characteristic feature is typically not environment dependent.

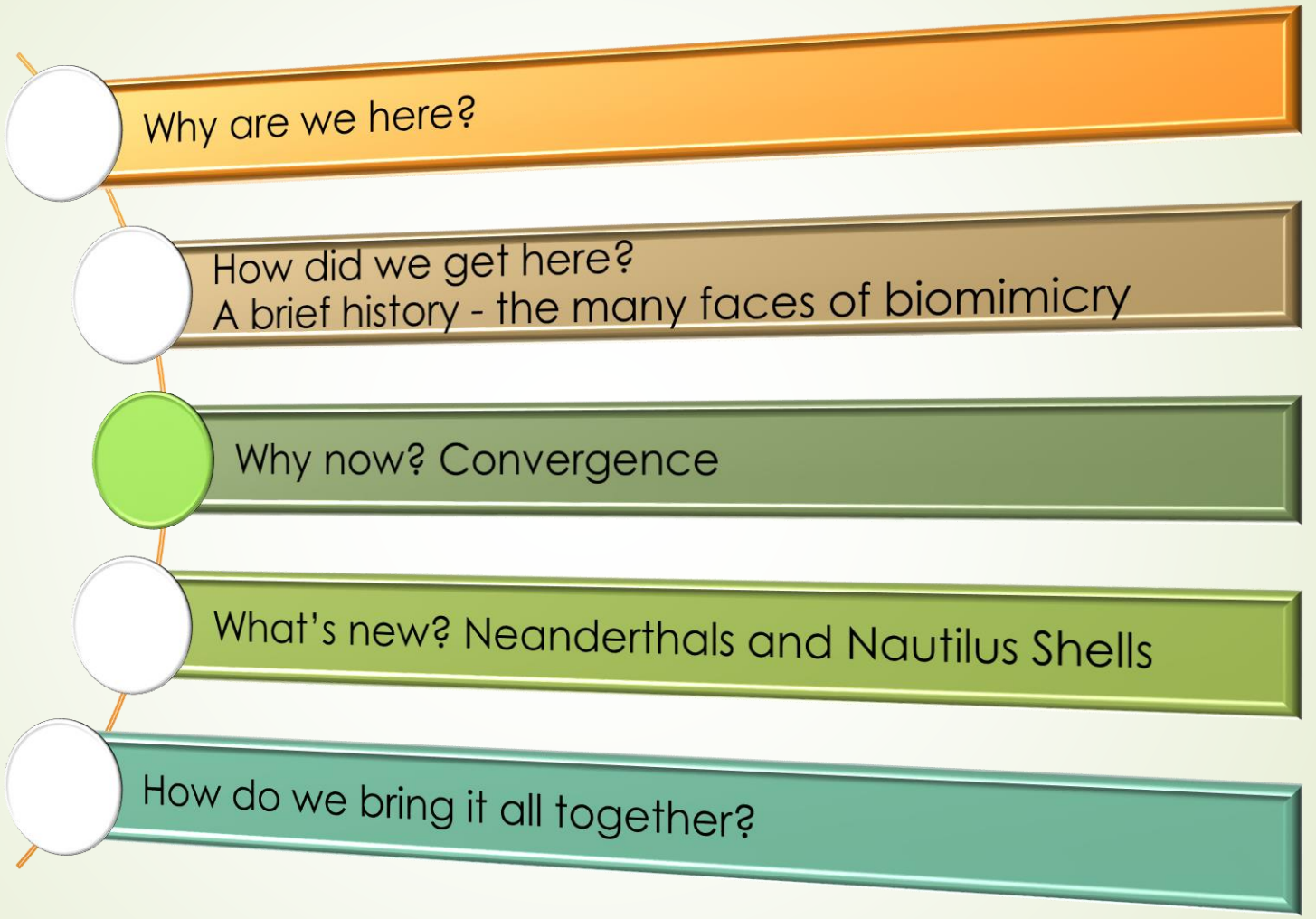
3) As biological research progresses, there is evidence that many basic principles are employed and adapted by many species to meet their specific functional requirements. It is these scientific principles which we seek to understand through bionics research; thus we adapt these principles to our engineering applications (even extraterrestrial) rather than mimic nature directly.

1.1 Bionics Contributions

Our study has uncovered a wealth of engineering contributions from the field of bionics. Many early flying machines were modeled after flying animals including DaVinci's designs of 1505 (bats), the Eole of 1890 (flying foxes), and the Etrich Dove of 1913. More recently, riblets and asymmetric nose cones (sharks) and leading edge combs (birds) have contributed to drag reduction, and filleted surface intersections (many fishes) have been used by the Soviets to quiet submarines.

Benefits extend beyond fluid dynamics; researchers have employed the laminated composite structure of seashells to achieve dramatic improvements in toughness of ceramic metal-matrix composites. One company, PA Technology, has adapted the non-reflective structure of the moth eye to reduce laser reflection from optical memory disks. Beginning with General Electric's adaptation of lateral inhibition (first noted in horseshoe crabs) for television and radar displays in the 1960s, research into human and animal vision has progressed, hand-in-hand, with design of machine vision and pattern recognition systems. Researchers at Caltech and elsewhere are now constructing VLSI retinas and incorporating active visual search behaviors into improved vision systems. Navy supported research into echolocation by bats and dolphin has contributed substantially to the design of sonar and radar signal processing.

Artificial neural networks and parallel processing computers have their roots in biology; yet, while powerful tools, their current capabilities are dwarfed by the complexity of processing accomplished by biological neural networks. Developers of multi-fingered robotic end-effectors have mimicked human hand motor control; while others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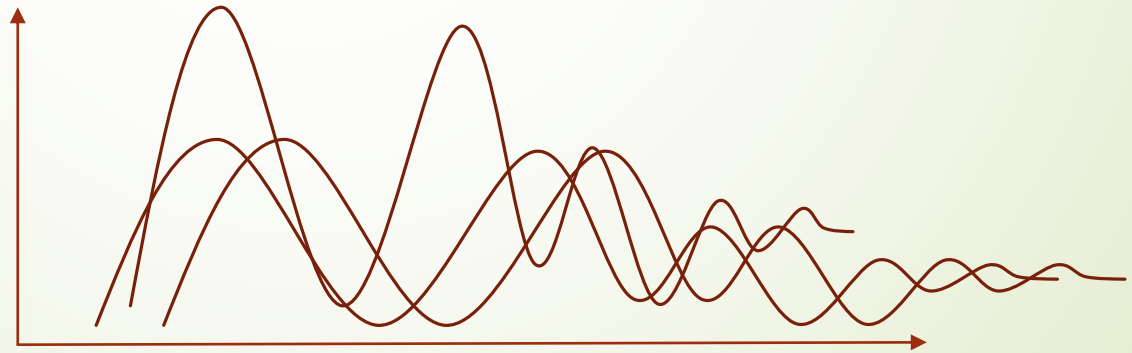
Patterns and optimality

- Nature uses similar patterns but tweaks them for different conditions.
- To observe a pattern we must phrase the question appropriately
- Spirals are used in nature to
  - Pack more efficiently (sunflower seeds)
  - Mix flow (vortices)
  - Maintain structural integrity (nautilus shell)
- Spirals are good at distributing mass, energy, force
- Similarly, sinusoids or bumps of varying amplitude, wavelength are found and are used for changing the frequency or amplitude of flow properties

Patterns and convergence

- These patterns exist even in human interactions
- Big ideas take time to develop. During this time there is division (think flat earth vs round earth)
- Generalists and specialists? Collective learning always feeds into formation of philosophy that tries to unify more and more of our collective learning through space and time.

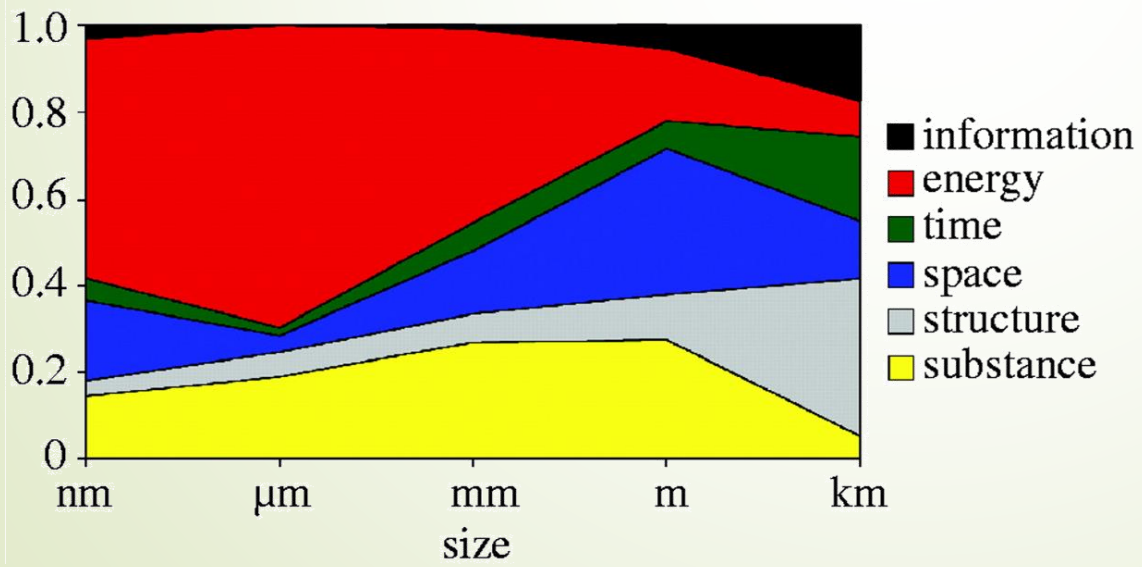
Political will
Agreement on ideas
Economic incentives
Challenges
Big ideas or unifying theories
Frustration/happiness
Productivity
…



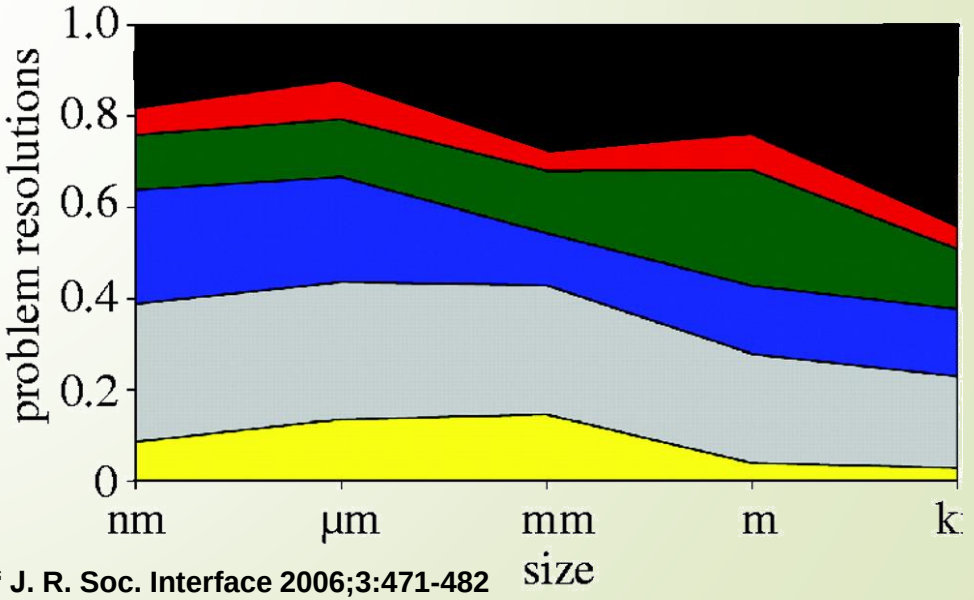
Time

The information age meets design by information

Human solutions create problems



Nature uses information to solve them



Julian F.V Vincent et al., "Biomimetics: its practice and theory" J. R. Soc. Interface 2006;3:471-482

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New perspectives

- Extinct species may be vast untapped resource for bio-inspiration
  - Average species lifespan is ~10M years. It is arrogant to assume that the species around us are somehow optimal or successful because they exist while we do
  - Some went extinct due to asteroid impact, mega-volcanoes, others were specialists and climate change caused competition that they were unable to adapt to.
  - New techniques like finite element analysis and swarm algorithms may enable researchers to piece together fossils and test hypotheses
- Ancient humans had to live without electricity and modern tools – they maintained temperature through city planning and ingenious design
- Earth's past may offer insights into extraterrestrial climes/life
  - NASA GEER facility – simulate past, predict future?
- Learn from behavioral response to extinction, climate change
- Learn from mistakes when we scatter to the stars…

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Physioteleology

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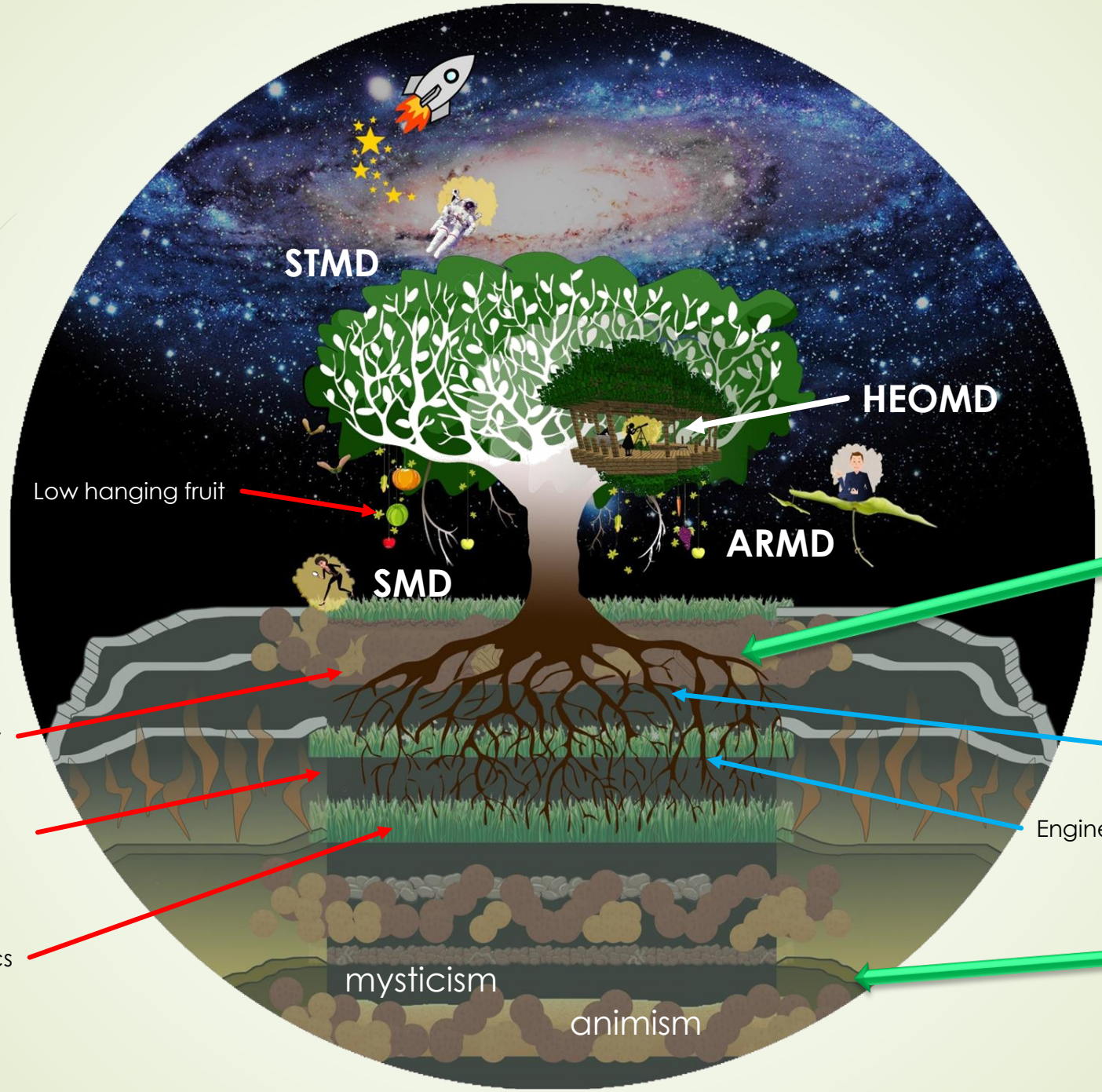
Sustainable Future

Summit Objectives…

- Establish a convergence of practitioners, disciplines, bio-inspired philosophy, tools, and research to benefit NASA, the nation and planet
- This will be accomplished through V.I.N.E. (Virtual Interchange for Nature-inspired Exploration). https://www.grc.nasa.gov/vine/
- The long term research vision of V.I.N.E is to create bio-inspired autonomous, self-sufficient, and sustainable systems that are responsive to their environments. This will also require a new way to approach engineering and design.

Nature-inspired Exploration on Earth and In Space For the Benefit of All Life

VINE Research Tree



Tools to absorb ideas based on philosophies

Bionics/Biomimicry

AskNature

Paleontology

Engineering

Newtonian physics

Philosophy

Credit: V. Vydyula

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Acknowledgements

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- Eric Bobinsky – Terasphere
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